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THE RECONSTRUCTION OF GRAND RIVER BRIDGE.

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Presented October 7th, 1896.

WITH DISCUSSION.

The reconstruction of the bridge over Grand River, 3 miles south of Chillicothe, Mo., on the Kansas City Division of the Chicago, Milwaukee and St. Paul Railway, by the railway company's Bridge and Building Department, presents several interesting features which will be described by the author, who was the engineer in charge of the work.

The Kansas City Division was built west from Chillicothe during the year 1887. The crossing of the Grand River consisted of a pile approach 1 070 ft. long at the east end, four 138-ft. wooden Howe truss spans across the channel, and a 16-ft. pile approach at the west end. The Howe trusses rested upon pile piers, each consisting of 48 oak piles well braced, planked on the outside, filled with rock and riprapped at the bottom. That these piers were well built is shown by subsequent events. Grand River, at the ordinary stage of water, is

about 150 ft. wide at the bridge, and from 4 to 6 ft. deep. It is subject, however, to very sudden rises, ranging from 10 ft. to 29 ft. above low water. At times of high water the current is very swift and carries large quantities of driftwood.

In 1894 it became necessary to renew the east pile approach, and it was decided that the Howe trusses must be replaced during the succeeding year. The wooden piers were in fair condition, and, inasmuch as they were good for at least two and possibly three more years, it was also decided that it would be best to replace the Howe trusses with iron spans of the same length, erected on the old piers, and then, when it became necessary to do so, to build new piers as near as practicable to the old ones, and on their completion to transfer the iron spans to them, the plan being to carry the wooden trusses as they were until the end of June, 1895, then to put in falsework and erect the iron during the fall. It was considered unwise to put falsework or strengthening bents under the trusses before this time on account of the danger from driftwood in case of high water. Grand River usually has a high June rise and is expected to stay at a comparatively low stage from then until some time in January.

During March, 1895, the second span from the east began to show evidence of weakness and three strengthening bents were driven under it as a measure of safety. The spring and summer were exceptionally dry, the usual June rise did not occur, and about July 1st it was thought to be safe to begin the falsework preparatory to taking down the spans and erecting the iron in the fall. This was started somewhat earlier than was necessary for iron erection purposes because the timber seemed to be deteriorating faster than had been expected. As a precautionary measure in case of high water, it was to be built last under the third span from the east, that being the channel span. During the middle of August a rise of the river occurred without serious consequences. On August 28th, the falsework was in the following condition. It was complete under the two east spans, and there was a bent of falsework at the third panel point from each end of each of the two west spans. At that date the river began to rise very rapidly, bringing down large quantities of brush, logs and whole trees, and did not stop rising until it had reached a stage about 20 ft. above low-water mark. In spite of all that could be done a jam was started at the bridge, against the falsework, which rapidly increased in size until a

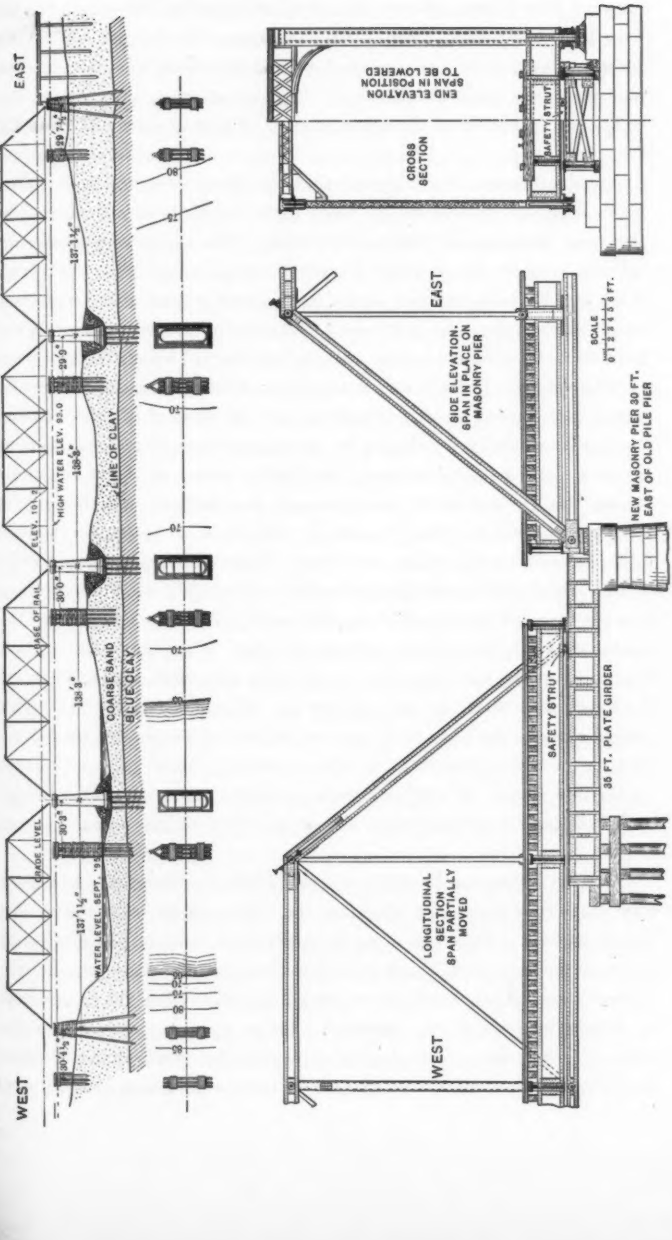
WEST
EAST
GRADE LEVEL
BASE OF RAIL
ELEV. 101.2
HIGH WATER ELEV. 93.0
WATER LEVEL, SEPT. '93
COARSE SAND
BLUE CLAY
LINE OF CLAY
30'4½"
137'1½"
30'3"
138'3"
30'0"
138'8"
29'9"
137'1½"
29'7½"
LONGITUDINAL SECTION SPAN PARTIALLY MOVED
WEST
SAFETY STRUT
35 FT. PLATE GIRDER
NEW MASONRY PIER 30 FT. EAST OF OLD PILE PIER
SIDE ELEVATION. SPAN IN PLACE ON MASONRY PIER
EAST
SCALE
CROSS SECTION
SAFETY STRUT
END ELEVATION SPAN IN POSITION TO BE LOWERED

FIG. 1.

mass of this driftwood from 4 to 12 ft. in thickness, extending the full length of the spans and 700 ft. up the stream, was lodged against the piers and falsework. One of the bents of falsework was carried away and one of the piers was thrown 8 ins., and another 5 ins. out of line at the top. A view of the accumulation of drift is shown in Plate IX, Fig. 1.

On examination it was found that the piers were not undermined by the current, but seemed to have been simply bent out of line by the great pressure exerted against them. They were apparently uninjured by their rough usage during the high water. The river subsided rapidly to its normal depth, leaving a large part of the driftwood on the sand at the sides. It was so intricately interwoven that it was impossible to separate a piece without cutting it loose from the rest.

The lodging of this immense amount of driftwood against the bridge put a new aspect on the situation, and in view of all the circumstances it was decided to begin the erection of the new spans as soon as the iron could be obtained from the bridge works, in order to permit taking out the falsework and clearing the channel, and instead of carrying the iron on the old piers for two or more years, to begin at once the construction of the new ones. It was decided also that the second, third and fourth piers from the east should be built of stone and the first and fifth should be pile piers. The two last are on the banks out of the line of the swiftest current. The piers were located, beginning at the east, respectively 29 ft. 7½ ins., 29 ft. 9 ins., 30 ft., 30 ft. 3 ins., and 30 ft. 4½ ins., east of the old piers (see Fig. 1). This was as close to the latter as it was convenient to work. On their completion the spans were to be moved endwise to their proper position on the new piers. It was with these problems confronting the Bridge and Building Department that the actual work of reconstruction was begun.

The first thing to be done was to finish building the falsework and traveler runway for erecting the iron and to take down the Howe trusses. This was done in September, and in the middle of October the iron crew began building their traveler, but were unable to begin the actual work of erection until November 1st on account of delays in getting the material. These were due in part to the difficulty the bridge works had in obtaining the required shapes from the mills, on account of the number of orders on hand, and in part

to the scarcity of cars for transporting the iron from the shops to the bridge site. This work was being done at a time when every car was needed to carry on the business of the railroad. Notwithstanding these delays, on November 19th the spans were all erected and riveting finished. The erection of the spans did not present any particularly interesting features. The four spans weighed 714 489 lbs., and the cost of iron and erection combined was 2.73 cents per pound. The cost here includes, as in all other cases where it is given, the amount paid in wages to the railway company's employees, and the cost of the material delivered at the most convenient point on the company's lines, and no other items. Iron and stone were purchased by weight, and timber by board measure, free on board cars on the company's lines.

Many schemes for disposing of the driftwood and clearing the channel were proposed. Several contractors asked permission to bid on the work, and offers ranging from $1 900 to $14 000 were made. It was decided, however, that the railway company was as well equipped for the work as any contractor; that it could do the work, which would be as novel to the contractor as to it, just as cheaply; that there was considerable uncertainty as to the cost; some risk to the bridge in case an attempt to burn the drift should be made, and that, all things considered, it would be unwise to contract for its removal. On November 11th the work of removal was begun in an experimental way, with the understanding that it should in no way be allowed to interfere with the building of the masonry. In preparing the foundations it was necessary to remove considerable drift which had lodged on the site of the new piers. This was done largely by hand and by teams, the wood being hauled to one side, piled and afterward burned. On November 14th a small crew of men and teams started to clear that which was piled against the wooden piers on the east side of the channel. The plan was to pull all of it which had lodged against the piers from them first; next to clear a space alongside and parallel with the bridge, in order to remove any danger in case it was decided to burn the wood, and then to set fire to a part of it to see if it would burn in a body. The method of procedure was to drag the logs with teams through the bridge to the sand bank below, after loosening them by chopping and the use of blocks fastened to the bridge. Fires were kept con-

tinuously burning the wood thus hauled, so that each night practically all which had been hauled out during the day was consumed. There was considerable fine stuff, twigs, small branches and cornstalks in with the logs, which caused much trouble, as it all had to be picked out by hand and hauled to the fires in wagons. It had to be taken out, however, in order to get at the logs.

On November 21st the driftwood around the piers east of the channel, and also a strip about 30 ft. wide parallel with the bridge, had been disposed of. The wind was blowing strongly from the bridge, and after trying one corner of the driftwood it was decided to set fire to all of it lying east of the channel. About 2 o'clock in the afternoon, after placing a steam-pump and 250 ft. of hose to protect the bridge, fires were started on the side next to the bridge and along the channel in a large number of places. In a few minutes the whole mass was in a blaze. It was a magnificent sight, burning rapidly, but without high flames or sparks. From time to time the wooden piers were wetted down to prevent their catching fire. By 6 o'clock in the afternoon the fine stuff was practically all consumed, and the logs were burning well, and it was in such shape that it was safe to let all but six men and the pump engineer go home for the night. The fire cleared up the driftwood east of the channel in good shape, except that here and there a pile of it was left unburned, and at the upper end quite a large section did not burn at all, due largely to the fact that the wind changed about the time the fire reached it, blowing the flames away. The fire did not cross the river.

The wood left unburned east of the channel was next collected, the idea being that after clearing each side of the channel it would be unnecessary to touch that which was in the water, as in case of high water it was expected the current would cut a new channel in the cleared space provided on the east side. This has been partly proved, as, during a small rise which occurred during the latter part of December, the river started to cut a new channel along the east side of the driftwood left in the water. This is an advantage, as it will stop the undermining of the west bank. The driftwood was cleared from the west pier, and on November 27th fire was set to that on the west shore. It did not burn as well as that on the east side on account of the fact that there had been snow. Some experiments were made with crude oil, but with little success. After disposing of

the drift on each side of the channel the long logs lying in the channel which were accessible were cut up, and it was considered perfeclty safe to suspend work upon it.

It was believed that inasmuch as this driftwood came down at a stage about 20 ft. above low water, very little more would come down until the same stage was reached again, and that as soon as the river began to rise the remaining drift would begin to float off, and by the time the river was high enough to bring any more, that lodged in the river, now there were no obstructions, would have floated away.

The cost of disposing of the driftwood was very small compared with the lowest estimate, the total cost for labor and material used being $938 78.

It was thought best to wait until the east iron span was erected before beginning the construction of the masonry, in order to avoid the confusion incident to two crews working at one end of the bridge at the same time. The east pier was selected to begin with on account of the necessity of locating the stone yard on the level ground just east of the east span. The stone was unloaded directly from the cars to the stone yard by a hand-power derrick, except for a short time toward the completion of the work when steam power was used. The pile bridge was of such height that the work of the yard derrick in unloading and piling the stone was lowering. Raising stone to any considerable height by a hand-power derrick is very expensive. The stone was delivered from the stone yard to the piers by a push car running on an elevated track made of timbers taken from the trusses and built so as to pass close to the south end of each pier. It was on the ground at the stone yard and was given enough grade so that the car loaded with stone needed only one man to manage it. The stone on the car at the pier was of such height that the work of the setting derrick was all lowering except for a few of the top courses.

The soil at the site of the three masonry piers consists of coarse sand extending to about 10 to 12 ft. below low water and then a stratum of blue clay. The foundations of the east and middle piers consist of 44 pine piles each, from 19 to 23 ft. long, extending from 10 to 16 ft. into the clay. The piles are cut off 2 ft. 2 ins. below low water, capped with 12 x 12-in. pine timber, and these covered with a platform of 8-in. timber. The piles were driven with a steam-power land driver, having a 3 000-lb. hammer, aided by a water-jet. The

latter was of material assistance in driving the piles through the sand. A 6 x 5¾ x 6-in. duplex Worthington pump with a 4-in. suction and a 2½-in. discharge was used to furnish water for the jet.

The foundation of the west or channel pier consisted of 44 pine piles from 21 to 23 ft. in the ground and cut off 4 ft. below low water. On these piles a caisson was sunk made of three thicknesses of 8-in. timber for the floor and 3-in. plank for the sides. Most of these plank had been used in the falsework as sway braces, and most of the piles used in the foundation of the three piers had also previously been used in the falsework. The masonry had courses ranging in thickness from 15 to 26 ins. with beds and joints not exceeding ⅜ in. Western Portland cement was used to set the footings, the lower three neat work courses, the coping and bridge seat stones. The rest of the courses were laid in Milwaukee cement. The mortar was composed of one part of cement to two parts of sand by actual measurement. The sand was obtained at the site and was an ideal mason sand. The stone used is a limestone obtained at Stone City, Ia., and is the stone which this railway company has principally used for its bridge work for some time past. It is soft, easily cut, and very durable. Frost has little effect on the ledges used for the company's work. Displacement of the hip stones when struck by logs or driftwood is prevented by securing each by one or more dowels extending about 8 ins. into the course below.

The foundation work was begun November 5th, 1895, and was completed January 2d, 1896. The stone cutting for the piers was begun November 7th, 1895; setting stone on the east pier was commenced November 24th, and the masonry was finished January 18th, 1896. The total cost of the foundations of the three piers was $2 374 40, or an average cost of $18 per pile driven. There are 715 cu. yds. of masonry, costing $5 747 30, or $8 04 per cubic yard. The cost per cubic yard, including the cost of foundation, was $11 36.

In designing the iron spans, the fact that they were to be moved longitudinally after erection was considered and the plan of moving was decided upon. In furtherance of this plan, the end floor beams were to be attached to the end shoes by means of vertical angles in such a way that the spans could be lifted and carried by them, the plan of moving being to pull the spans, one at a time, on small rollers running on the top of a 35-ft. iron girder span reaching from the old

to the new pier at each end of the span being moved. For this purpose two 35-ft. plate girder spans were constructed after the general plan of one of the company's types of deck girder spans, except that the weight was increased about 14%, and on the top of each girder a $\frac{3}{4}$-in. plate 10 ins. wide was riveted with countersunk rivets. The girders were spaced 9 ft. center to center. The cross-frames and laterals were to be connected by means of bolts, so that the girders could be placed in position, bolted up, and after use unbolted and taken out separately. These girders are to be put in service as ordinary bridges now that the spans have been moved. Twenty-eight $2\frac{1}{4}$-in. rollers, with shoulders projecting $\frac{1}{4}$ in., were made to run on the top of the girders. These rollers were $10\frac{1}{8}$ ins. between shoulders, and 12 ins. long over all. They were made to fit the plate on the top of the girders closely, so that they would run true while in use. Four shoes 12 ins. long and 10 ins. wide, to be clamped to the lower flange of the end floor beams directly above the moving girders, were made to fit between the shoulders of the rollers. Two struts of two 6 x 4 x $\frac{5}{8}$-in. angles each were clamped to the lower flanges of the stringers a short distance from the end floor beams. When in position, with the span raised and resting on the rollers, each strut extended over the top of the moving girders, clearing the top plate $\frac{1}{4}$ in. both above and at the side. Its province was to catch the span after a drop of $\frac{1}{4}$ in. and to prevent any lateral motion in case the shoes ran off the rollers.

Wooden shores were to be placed between the top of the second floor beam from each end and the top chord to prevent buckling of the span in this case. Fig. 1 shows a span partially moved and gives the details of the moving device. Each end of the span in process of being moved was to be raised by means of four 25-ton hydraulic jacks, two on each side, under the end floor beams, between the moving girders and the end shoes. The rollers were then to be placed under the shoes on the girders and a locomotive attached to the span to pull it ahead. The plan contemplated was to pull the spans one at a time at intervals measured by the length of time necessary to take up the moving girders at the front of the span last moved and to place them in position under the rear of the span next in order. Each moving girder span between the truss spans would carry the rear end of one span and the front end of the next span without being shifted. During the intervals, after moving one span and while preparing to move

the next one, the track between these two spans was to be carried on blocking resting on the moving girder span in position between them.

The ends of the girders resting on the new piers were placed at such a height that when the truss span had rolled into position it would be 0.5 in. higher than when lowered to the pier. The other ends on the old piers were raised 1 in. higher, in order to give a downgrade to assist in the moving. This was effected by putting shims of the proper thickness under the ends of the girders resting on the new masonry piers and on the wooden piers at the expansion ends and by cutting down to give the proper elevation at the fixed ends. Between February 1st and 8th all work preliminary to moving the spans was completed and everything put in shape, so that when the moving was once started there would be no delays on account of lack of preparation. On the afternoon of February 8th, which was Saturday, the track ties between the east new pier and the east old one were cut off and the stringers shoved in far enough to permit setting the first girder span early in the morning of February 10th. The first thing done on that date was to set in place the girders of this span, using the derrick cars which have been specially designed by the Bridge and Building Department for iron bridge erection. This span was to carry the front end of the east truss span. After landing these girders, those for the rear end of this span were put in place, which was a more difficult task, inasmuch as the girders were 35 ft. long and the truss panel length was only 22 ft. 6 ins. It was accomplished by leading them endwise, by means of the derrick cars, through the end panel between the batter post and the hip vertical.

The two girders at the front end of the span and one of those at the rear end were lowered into position by noon. In the afternoon the other girder was placed, the cross-frames and laterals of both spans put in and the bolting up almost completed. During the next morning this work was finished and the girder spans were centered exactly to position. The center of the end on the old pier was made to coincide with the center of the truss, and the end on the new pier was centered with reference to the center line desired for the new position of the bridge, which was $1\frac{1}{2}$ ins. south of the old center line. This would cause the spans to move laterally $1\frac{1}{2}$ ins. while going 30 ft. longitudinally.

The piles between the east end of the truss span and the east new pier were cut out and the track blocked up on the moving girder span. The tackle with which the locomotive was to do the pulling was fastened to the end batter posts and laid ready for use. Everything was made in readiness to move this first span between 12.45 P. M., when passenger train was due from the west, and 3.20 P. M., when another passenger train was due from the east. After the passage of the train at 12.45 P. M. the track was torn out ahead of the span and the material piled at the east end of the second span, in the order in which it would be needed to block between the first and second spans. While the carpenter crew was doing this work the iron crew was engaged in jacking up, first the east and then the west, end of the span, clamping the roller shoes on the lower flanges of the end floor beams, then lowering them down on the rollers placed on top of the girders. The safety struts were put in place and the locomotive attached to the steel cable by which the span was to be moved. This cable was attached at one end to the batter posts a short distance above the level of the track. It was so arranged with a double and triple block as to give six parts to the line. This was done to reduce the speed of moving slower than it would be practicable to run the locomotive. The other end was fastened to a chain which was attached in turn to the drawhead of the locomotive by passing a coupling pin through one of the links. In order to stop suddenly if it were wished to do so, block and tackle were fastened between the rear batter posts of the span to be moved and the front batter posts of the next span, and men stationed at these lines for that purpose. The force was placed as follows:

The conductor and brakeman of the work train near the engine to pass the signals to the engineer.

Three men to look after the moving tackle.

Two men at each moving shoe, one of whom fed the rollers in front of the shoe as the other passed them to him as they came out behind; each shoe rested on five rollers, thus leaving two extra ones.

One man stood at each end of the span where he could watch the operation of the rollers at his end and give signals to regulate the speed when necessary.

Two men were detailed to pay out the snub lines at the rear.

One man was sent out in each direction to flag approaching trains.

The carpenter foreman and crew of eight men were stationed at the front end of the second span to block up on the moving girders and to put in the temporary track as fast as the gap behind the span opened.

At 1.43 P. M. the locomotive started to pull the span and at 2.02 it had reached its proper position ready to be lowered to the new piers. At 2.40 P. M. the spans were let down on the piers, the track connected up at the east end of the span and everything in shape for traffic. At 2.55 P. M. an eastbound freight train crossed the bridge. The actual time during which the track was disconnected was 1 hour and 55 minutes. The time consumed in pulling this first span across the distance from the old to the new piers was 19 minutes. The girders at the front end of this span were picked up and loaded on the cars before night, ready to set down at the rear of the second span the next morning. Those in the rear of the first span were all ready to carry the front of the second span.

The next day the weather was bad and no work was done. On the following morning the girders were lowered into place at the rear of the second span. This span was moved after 3.20 P. M. the same day. The operation of moving the second, third and fourth spans was practically the same as that of moving the first. The last two spans were moved on February 14th and 15th respectively.

TABLE GIVING TIME CONSUMED IN MOVING EACH SPAN.

Span number from east.	Date when moved.	Track was disconnected at.	Started to pull span at.	Span reached new position at.	Track ready for traffic at.	Length of time track was impassable.	Length of time required to pull span from old to new position	Distance moved by span.
		P. M.	P. M.	P. M.	P. M.	H. M.	Min.	Ft. Ins.
No. 1...	February 11th, 1896....	12.45	1.43	2.02	2.40	1 55	19	29 7⅞
No. 2...	" 13th, "	3.30	4.06	4.16	4.45	1 15	10	29 10
No. 3...	" 14th, "	3.30	4.18	4.24	4.55	1 25	6	30 1
No 4...	" 15th, "	3.30	3.49	4.16	4.50	1 20	27*	30 4½
	Average...............	....	....	....	....	1 20	15½	

* Fifteen minutes' delay due to a shoe working loose and becoming skewed.

A view of the last span when half moved is shown in Plate IX, Fig. 2.

On February 17th the girders were picked up and loaded on the cars for shipment.

The time consumed in moving the four spans was 6½ days. The locomotive used was a Rhode Island 17 x 24-in. cylinder, eight-wheel engine, weighing 86 150 lbs., 54 450 lbs. on the drivers. The engineer reported the pull to be very light. There was no trouble in starting or stopping.

The total cost of moving the spans was $716 81, or an average of $179 20 per span. After moving, the track was lined, the floor finished, the old piers removed and their rock filling used to rip-rap the new piers. Everything was finished March 15th, 1896. A statement showing the cost in detail is given at the end of the paper.

During the reconstruction of this bridge there were no delays to passenger trains and rarely to freight trains, and these never exceeded ten minutes. During the erection and moving of the iron spans each train was required to come to a full stop during working hours and receive a signal before crossing the bridge, and to reduce speed while crossing the bridge during the night. The rest of the time trains reduced speed during working hours only.

Notwithstanding the unusual character of part of this work it was all done on week days. Experience in the Bridge and Building Department has shown, aside from questions of principle, that as a rule Sunday work is more expensive and no safer than that done on week days.

Plans and specifications, including all working drawings, were made by the Bridge and Building Department of the Chicago, Milwaukee and St. Paul Railway Company. All work at the bridge site was performed by the company's employees, and every item of construction from beginning to end was carried out by the department.

CONDENSED STATEMENT OF COST.

Falsework, taking down Howe Trusses and Repairing old Piers.

Labor		$1 834 99		
Train service		150 00		
			$1 984 99	
Material			1 606 90	
				$3 591 89

Two Pile Piers.

Labor		$287 00		
Train service		40 00		
			$327 00	
Material			420 24	
				747 24

Three Masonry Piers.

Foundation—				
Labor		$1 773 00		
Material		601 40		
			$2 374 40	
Stonework—				
Labor		$3 485 53		
Material—				
232 sacks Western Port. cement	$109 65			
269 sacks Milwaukee cement	67 25			
34 308 cwt. bridge stone	2 061 93			
Miscellaneous	22 94			
		2 261 77		
			5 747 30	
				8 121 70

Ironwork.

Labor erecting		$1 952 97		
Train service		96 78		
			$2 049 75	
Material—				
700 009 lbs. wrought iron		$1 7216 91		
14 489 lbs. cast iron		195 43		
Miscellaneous		21 06		
			17 433 40	
				19 483 15

Floor.

Labor			$292 82	
Material			1 051 32	
				1 344 14

Moving the Spans.

Labor		$521 99		
Train service		58 20		
			$580 19	
Material—				
2 523 lbs. iron (shoes, struts, etc.)		$69 38		
2 445 lbs. iron (increased weight of two moving girder spans)		67 24		
			136 62	
				716 81

Removing old piers, pulling piles, taking out falsework	593 05
Removing driftwood	938 78
Night watchman	465 50
Engineering, office expenses and inspection of stone and iron	1 145 96
Total cost	$37 148 22

Analysis of Cost.

The falsework, taking down the Howe trusses and repairing the old piers cost \$6 53 per lineal foot.

The new pile piers cost \$373 62 each.

The foundation of the three masonry piers cost an average of \$18 per pile driven.

The stonework cost \$8 04 per cubic yard, exclusive of foundation, and \$11 36 including foundation. Each cubic yard of finished masonry required 48 cwt. of stone in the rough, and the cost of the labor per cubic yard averaged \$4 87.

The erection of the iron spans cost 0.29 cent per pound, and the erection and material together cost 2.73 cents per pound.

The floor of the iron spans, including the heavy iron angle guard rail, cost in place \$22 22 per thousand feet, board measure, of timber used, or \$2 44 per lineal foot of floor.

The cost of moving the four spans averaged \$179 20 each or 0.1 cent per pound.

The engineering, office expenses and inspection of stone and iron formed 3% of the total cost.

CORRESPONDENCE.

Mr. Bates. ONWARD BATES, M. Am. Soc. C. E.—The author has wisely omitted the details of design, the knowledge of which may be acquired in office practice or in the text books, and confined himself to the practical execution of the plans. The elements of time consumed, labor and material employed and costs, all have to be taken into consideration in the execution of similar work, and information of this class contained in the paper is especially valuable to those who are in charge of such work. Good judgment seems to have been exercised in laying out the work, and this is in a measure checked by the reasonableness of the items of cost. The care with which the work was planned and executed is shown by the use of safety struts, which would permit of a vertical drop of only ¼ in. and no lateral motion in the event of the spans running off the rollers, and in the nice adjustment of grade in the plate girders which acted as a track, reducing the friction in moving the spans.

The problem of the removal of such a mass of driftwood interlocked and settled in the sand, as described in the paper, appeared a difficult one when $14 000 was asked by a contractor for its removal, and the author was favored by the condition of low water which permitted the drift to be burned. If the stage of water had been high enough to keep the driftwood wet, it is probable that $14 000 would have been none too much as the price for its removal. The writer, who has some personal knowledge of this structure, is able to say that during the high water of June, 1896, all of the driftwood which would float away was lifted and carried off. Some of it, however, had become so imbedded in the sand that it remains there and had the effect of turning the main channel away from the west bank and carrying it under the second span from the east end, which is the most desirable location for it.

Mr. Low. EMILE LOW, M. Am. Soc. C. E.—The extremely short life of the original Howe truss bridge built across the Grand River is notable. The author states that these spans were erected in 1887, and replaced by iron in 1895, being only eight years in service. Referring to Plate IX, Fig. 1, which shows an end view of the original structure, it is apparent that the bridge was not housed in. Exposure to the weather evidently hastened the decay of the timbers, the life of which would undoubtedly have been prolonged had precautionary measures of some kind been resorted to.

The author does not mention the kind of timber employed in the trusses, but it was probably some species of southern pine, which, it seems, cannot be relied upon in exposed situations for a longer period than about eight years. In this respect it does not compare favorably

with the pines of the Northern States, as the writer has knowledge of bridges lasting more than double this period. Timber structures on a southern railroad with which the writer was connected, consisting of ordinary trestles and Howe truss bridges, were erected during the years 1887 to 1890. The Howe trusses were uniformly constructed of southern pine, while the trestles were almost exclusively built of white oak, with southern pine stringers, except in a few trestles where oak stringers were used. These pine stringers are now showing evidences of decay, and in consequence numbers of them are being taken out and replaced. Many sills have also been taken out and new ones substituted. These sills rested upon blocks 4 ins. thick, supported upon stone masonry, the tops of which were well above the surface of the ground. The original sills were in one piece, 10 x 12 ins. in cross-section, while the new ones are composed of two pieces, each 5 x 12 ins. in section. In addition to the stringers and sills, large numbers of the cross-ties in these trestles had to be removed. Mr. Low.

The parts which need to be replaced are those lying in a horizontal position. The upright parts, such as posts, are still serving their purpose, and are not showing very perceptible signs of failure, the only exception being that some of the oak posts were so badly warped as to necessitate their removal. The length of these pieces is about 26 ft., and they are from 10 x 12 ins. to 12 x 12 ins. in section.

From an examination of the Howe trusses the fact is developed, that while portions of the chords are showing signs of decay, the braces are comparatively sound.

The importance of suitably covering wooden bridges does not seem to be well recognized. It cannot be denied that this protection adds materially to the length of their usefulness. Timbers which, from their position in the structure, are more susceptible to decay, should be treated with preservatives of some kind. Owing to the peculiar construction of wooden structures it is not always easy or economical to replace a defective piece, such repairs oftentimes necessitating as elaborate and expensive scaffolding as would suffice for the substitution of a large number of pieces.

Another great advantage gained by covering wooden structures, and especially the stringers, is the immunity afforded from fire. In an instance which came under the writer's observation, a stringer of a certain trestle caught fire from a passing train, but was fortunately discovered before any great harm had been done. In making repairs, instead of taking out the injured member, it was left in position, and additional new pieces put in, one on each side, leaving the charred piece in the middle. On account of its condition it was extremely liable to ignition, and it was not long afterwards that the same trestle was again on fire. This, however, was not discovered in time and resulted in the wrecking of a freight train, which, being loaded

Mr. Low. with goods of an extremely valuable character, caused a considerable loss.

Referring to the analysis of cost at the end of the paper, the great decline in the cost of bridges since 1887 is forcibly illustrated. The writer desires to compare the cost of Howe truss bridges erected in that year with the cost of iron spans now at the figures given by the author. He recalls one Howe truss span of 76 ft. which cost to erect in 1887 $27 75 per linear foot, or a total of $2 109. Assuming an iron bridge of the same span to weigh 60 000 lbs., at the price given by the author, 2.73 cents, the cost would amount to $1 638, not including the floor.

FIG. 1.

FIG. 2.